INDOOR AIR QUALITY ASSESSMENT

Helen R. Donaghue Elementary School
24 Union Street Extension
Merrimac, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
August 2003

Background/Introduction

At the request of Steven Tummino, Head Custodian, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Helen R. Donaghue Elementary School (DES) in Merrimac, Massachusetts. The request was prompted by concerns for indoor air quality throughout the school building.

On April 16, 2003, a visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, Environmental Analyst of the Emergency Response/Indoor Air Quality (ER/IAQ) program, BEHA, and Sharon Lee, Environmental Analyst, ER/IAQ Program. BEHA staff was accompanied by Mr. Tummino for portions of the assessment.

The school is a two-story brick building constructed in 1951. A two-story addition was constructed in 1994. General classrooms, as well as a computer room and library are located on the second floor. The ground level is comprised of general classrooms, school nurse's office, cafeteria, kitchen, teachers' room, art room, music room, activity room, gymnasium and office space. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

This school services approximately 400 students in grades K–6, and also has a staff of approximately 40. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in 16 of 35 areas surveyed, indicating inadequate ventilation in many areas of the school. As indicated in Table 1, a large number of classrooms had open windows during the assessment. Open windows can greatly reduce carbon dioxide levels. Of note is room 12, which had a carbon dioxide level of close to 2,000 ppm, even with windows and a door open. This measurement indicates a lack of air exchange in this room. Several other classrooms also had elevated carbon dioxide levels, despite open windows and doors (Table 1).

Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents have three controls: low, high and off. Univents were deactivated or providing weak airflow in many classrooms throughout the school. Obstructions to airflow, such as furniture located in front of univents or materials stored on univents, were also observed in a number of classrooms

(Picture 1). In order for univents to provide fresh air as designed, these units must remain "on" and allowed to operate while rooms are occupied. In addition, intakes must remain free of obstructions.

The mechanical exhaust ventilation system consists of ceiling and wall-mounted exhaust vents connected to exhaust fans on the roof. Exhaust ventilation is designed to operate continuously; however, a number of exhaust vents were not functioning during the assessment. According to Mr. Tummino, exhaust vents were undergoing repair in a number of areas. In addition, wall vents were blocked by desks, cabinets, and other furniture (Picture 2). As with the univents, in order for exhaust ventilation to function as designed, they must be activated and remain free of obstructions. Without exhaust ventilation, indoor air pollutants can build up and lead to indoor air quality/comfort complaints.

Mechanical ventilation in the gymnasium and cafeteria is provided by ceiling-mounted air handling units (AHUs) activated from a control panel. Units were set to the "auto" setting (Picture 3). The automatic setting on the control panel activates the AHUs at a preset temperature. Once a preset temperature is measured by the thermostat, the HVAC system is deactivated. Therefore no mechanical ventilation is provided until the thermostat re-activates the system.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not

available at the time of the assessment. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat

irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix I.

The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. Temperature measurements ranged from 71° F to 80° F, which were close to the BEHA recommended comfort range. A number of temperature control complaints were expressed to BEHA staff during the visit. It is difficult to control temperature and maintain comfort in a building without operating the HVAC equipment as designed (e.g. univents deactivated/exhaust not functioning). In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. The relative humidity measured in the building ranged from 33 to 42 percent, which was below the BEHA recommended comfort range in most areas. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A number of conditions conducive to microbial growth were noted at the DES. A water fountain is located in a carpeted hallway outside the custodian's office (Picture 4). Carpeting directly beneath the fountain is water damaged. To avoid water damage to

carpeting and/or prevent potential mold growth, a water-resistant material such as plastic or rubber matting should be installed beneath water fountains and/or water coolers. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that carpeting be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If carpets are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy carpeting is not recommended.

Water coolers are located in lounge areas. Standing water and debris were noted in catch basins (Picture 5). Stagnant water can provide a medium for bacterial and microbial growth. To prevent growth, catch basins should be emptied and cleaned regularly.

In a number of classrooms, spaces between the sink countertop and backsplash were noted (Picture 6). Improper drainage or sink overflow could lead to water penetration. If the seam is not watertight, water can penetrate the and collect behind the countertop or cabinets or in cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth.

Several classrooms contained a number of plants. Some plants were noted in standing water (Picture 7). In several classrooms, plants were found on top of univents. Containers with potting soil (no plants) were found in room 11. Plants, soil and drip pans can serve as sources of mold growth, thus should be properly maintained. Plants should have drip pans to prevent wetting and subsequent mold colonization of window frames. Over-watering of plants should be avoided, and drip pans should be inspected

periodically for mold growth. Plants should also be located away from univents and ventilation sources to prevent aerosolization of dirt, pollen or mold.

Several rooms contained aquariums and terrariums (Table 1). Some aquariums and terrariums had mold or algae growing on the glass surface (Picture 8). Room 20 contained an aquarium with a decaying fish body floating at the surface (Picture 9). Aquariums and terrariums should be properly maintained and cleaned to prevent bacterial growth, mold growth and nuisance odors.

A number of hallways had water-damaged ceiling tiles, which can indicate leaks from either the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired.

A survey of the building exterior revealed a number of potential sources of water penetration:

- One wall in the school courtyard has substantial clinging plant growth (Picture 10). Clinging plants can cause water damage to brickwork through the insertion of tendrils into brick and mortar. Water can penetrate into the brick along the tendrils, which can subsequently freeze and thaw during the winter. This freezing/thawing action can weaken bricks and mortar, resulting in damage to this wall. In order to avoid this problem, clinging plants on brickwork is not recommended.
- Shrubbery and other plants exist in close proximity to the foundation walls (Picture 11). The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building

envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

- Along the perimeter of the building, some of the univent fresh air intakes are located at ground level, near plant and soil (Pictures 11 and 12). Debris and plant matter were found in the intakes (Picture 13). Care should be taken to ensure that fresh air intakes remain clear of obstructions (e.g. snow, shrubbery) to avoid the entrainment of dirt, moisture and or pollen.
- The exterior walls had spaces/cracks in brickwork. In many areas mortar around exterior brickwork appears to be crumbling or missing (see Picture 14). Picture 15 shows open utility holes in exterior brickwork, which can serve as an entryway for pests. These conditions are breaches of the building envelope and provide a means for water entry into the building. Repeated water penetration can result in the chronic wetting of building materials and the potential for microbial growth. In addition large wall cracks may provide a means of egress for pests/rodents into the building.

In each of these instances, water can penetrate into the DES interior and moisten building components, which can result in water damage and potential microbial growth.

In one instance, microbial growth was observed to be growing on exterior window caulking (Picture 16). This material should be cleaned and disinfected with an appropriate antimicrobial agent and cleaned with soap and water.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. Cleaning products and other chemicals were found in floor level

cabinets and on counter tops in several classrooms (Picture 17). Cleaning products contain chemicals (such as bleach or ammonia-related compounds), which can be irritating to the eyes, nose and throat. In some cases products found were labeled flammable or contained acetone, an organic solvent. These items should be stored properly and out of the reach of students.

Accumulated chalk dust was noted in some classrooms. Chalk dust is a fine particulate, which can be easily aerosolized and is an eye and respiratory irritant. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

A number of classrooms contained upholstered furniture (Picture 18). Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis or every six months if dusty conditions exist outdoors (IICR, 2000).

Also of note was the amount of materials stored inside classrooms (Picture 1). In classrooms throughout the school, items were seen piled on windowsills, tabletops, counters, bookcases and desks. The large amount of items stored in classrooms provides

a means for dusts, dirt and other potential respiratory irritants to accumulate. Many of the items, (e.g. papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to the eyes, nose and respiratory tract. These items should be relocated and/or cleaned periodically to avoid excessive dust build up.

A number of exhaust vents in classrooms were noted with accumulated dust (Picture 19). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles. Personal fans were also observed to have a thick layer of accumulated dust that can become re-aerosolized when the fan is in use (Picture 20).

Items were observed hanging from ceiling tiles (Picture 21). The movement or damage to ceiling tiles can release accumulated dirt, dust and particulates that accumulate in the ceiling plenum into occupied areas. As previously discussed, dust can be irritating to the eyes, nose and respiratory tract. Building occupants should refrain from hanging objects from ceiling tile systems.

A vacuum cleaner was noted in the custodian's office with the vacuum hose secured by duct tape (see Picture 22). In this condition the hose can periodically loosen to provide the opportunity for the reaerosolization of dirt, dust and particulates into the environment.

Inactive wasps' and birds' nests were noted in classrooms and reportedly serve as learning props. Insect parts can become dried out and aerosolized and may serve as a source of allergenic material for certain sensitive individuals. Bird's nests can contain bacteria and may also be a source of allergenic material. Nests should be stored in re-sealable plastic bags to prevent aerosolization of allergenic materials (Picture 23). These

items should also be located away from univents to prevent the aerosolization of insect parts and/or allergenic material.

The publishing center contained multiple photocopiers. Although local exhaust ventilation exists, it was not functioning. Photocopiers can produce VOCs and ozone, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). Without mechanical exhaust ventilation, pollutants produced by office equipment can build up. These machines also produce heat. To help reduce odors, pollutants and excess heat in the copy room, local exhaust ventilation should be activated while equipment is in use.

Finally, during the perimeter examination of the building, a wasps' nest was observed along the exterior wall (Picture 24). To prevent potential problems, these nests should be removed in a manner so as to prevent the use of pesticides and/or prevent insect movement into the building.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy independent of classroom thermostat control.
2. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Operate univents while classrooms are occupied. To increase airflow, set univent controls to "high".

Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers school-wide.

3. Inspect exhaust motors and belts for proper function, repair and replace as necessary.
4. Remove all blockages from univents and exhaust vents.
5. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Replace/repair any remaining water-stained ceiling tiles and building materials. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
8. Move plants away from univents in classrooms. Ensure all plants are equipped with drip pans. Examine drip pans for mold growth and disinfect areas of water leaks with an appropriate antimicrobial where necessary. Consider reducing the number of plants.
9. Consider having exterior brick re-pointed and waterproofed to prevent water intrusion.
10. Clean and maintain aquariums and terrariums to prevent bacterial/mold growth. Remove decaying fish from aquarium in classroom 20.

11. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Inspect wallboard for water-damage and mold/mildew growth, repair/ replace as necessary. Disinfect areas with an appropriate antimicrobial, as needed.
12. Store cleaning products properly and out of reach of students. Store flammables in a flameproof cabinet.
13. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
14. Consider replacing HEPA filtered vacuum, or obtain proper replacement parts to allow for proper function of equipment.
15. Clean chalkboards and trays regularly to avoid the build-up of excessive chalk dust.
16. Seal all utility holes, wall cracks and any other possible pathways to prevent the egress of materials into the school.
17. Remove wasp's nests from perimeter of the building in a manner as to not introduce insects and/or pesticides into the building.
18. Store nests used for educational purposes in sealed containers and away from ventilation units.
19. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA document, "Tools for Schools". This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
20. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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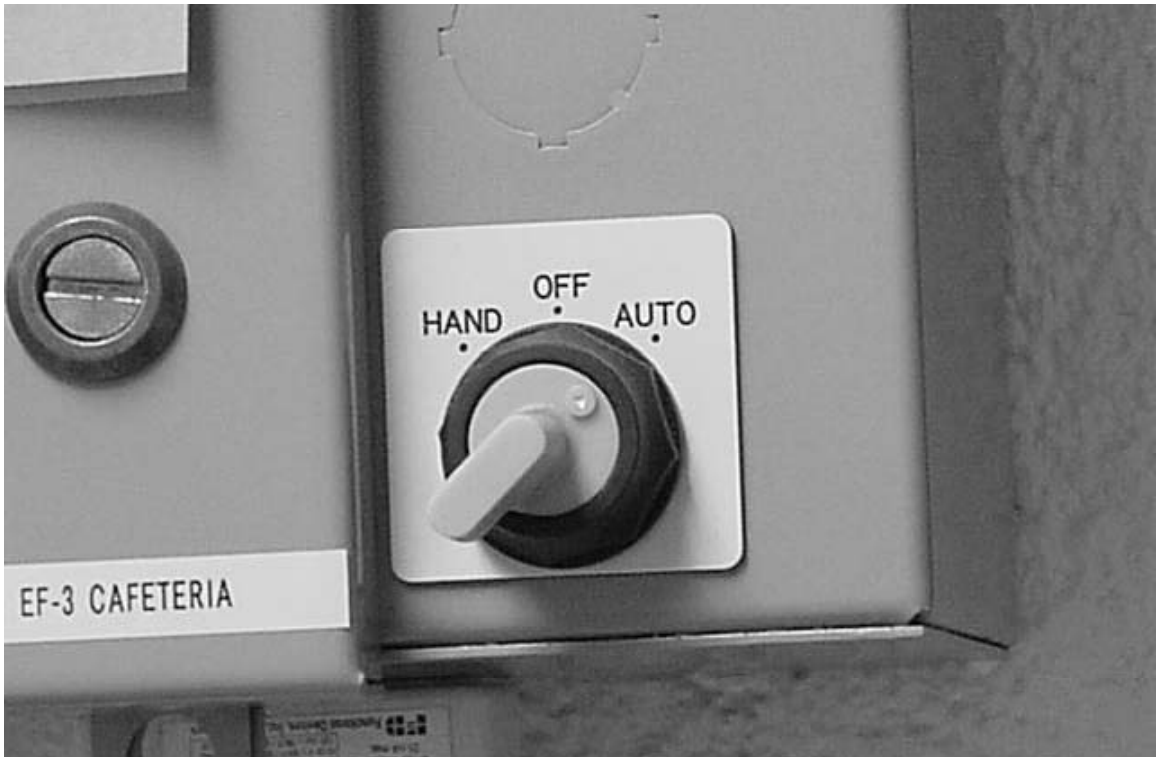
Picture 1

Plant and paper goods stored in front of univent return vent

Picture 2

Wall-mounted exhaust vent blocked by bookcase

Picture 3

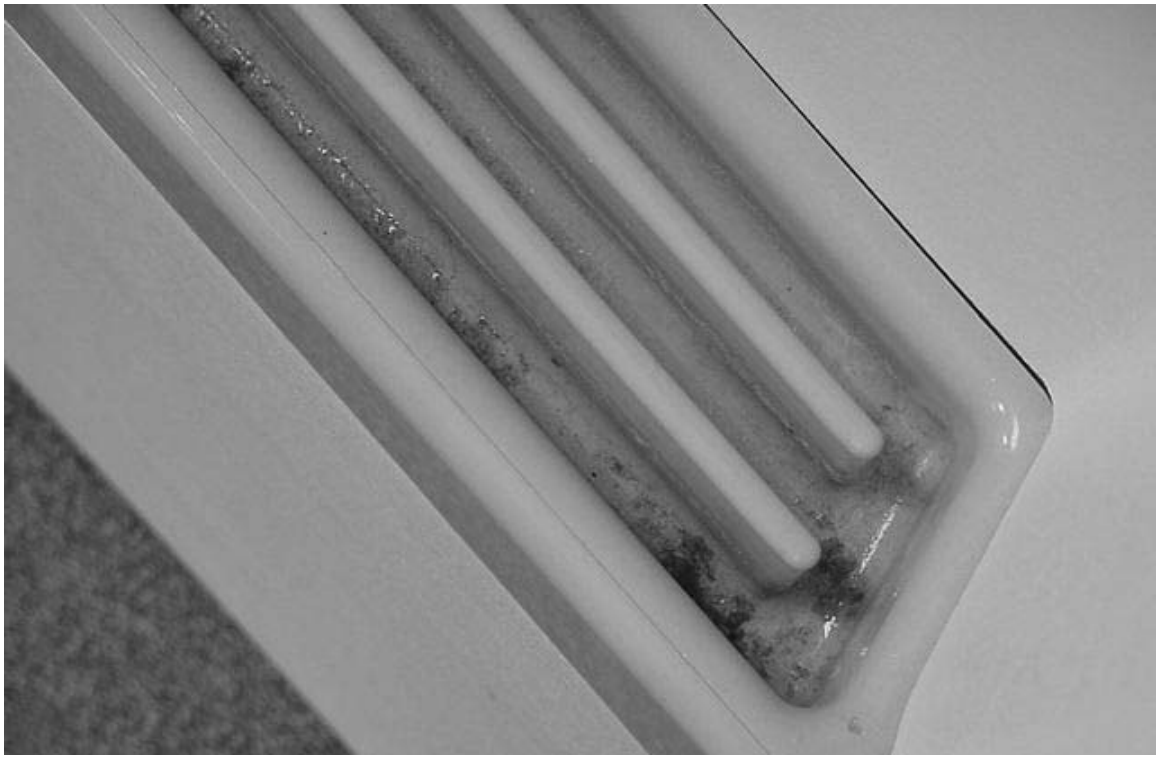


AHU set to ‘automatic’

Picture 4

Water damage to carpeting

Picture 5



Standing water in bubbler catch basin, dark stains indicate accumulated debris/microbial growth

Picture 6

Breach between countertop and splashboard in sink area

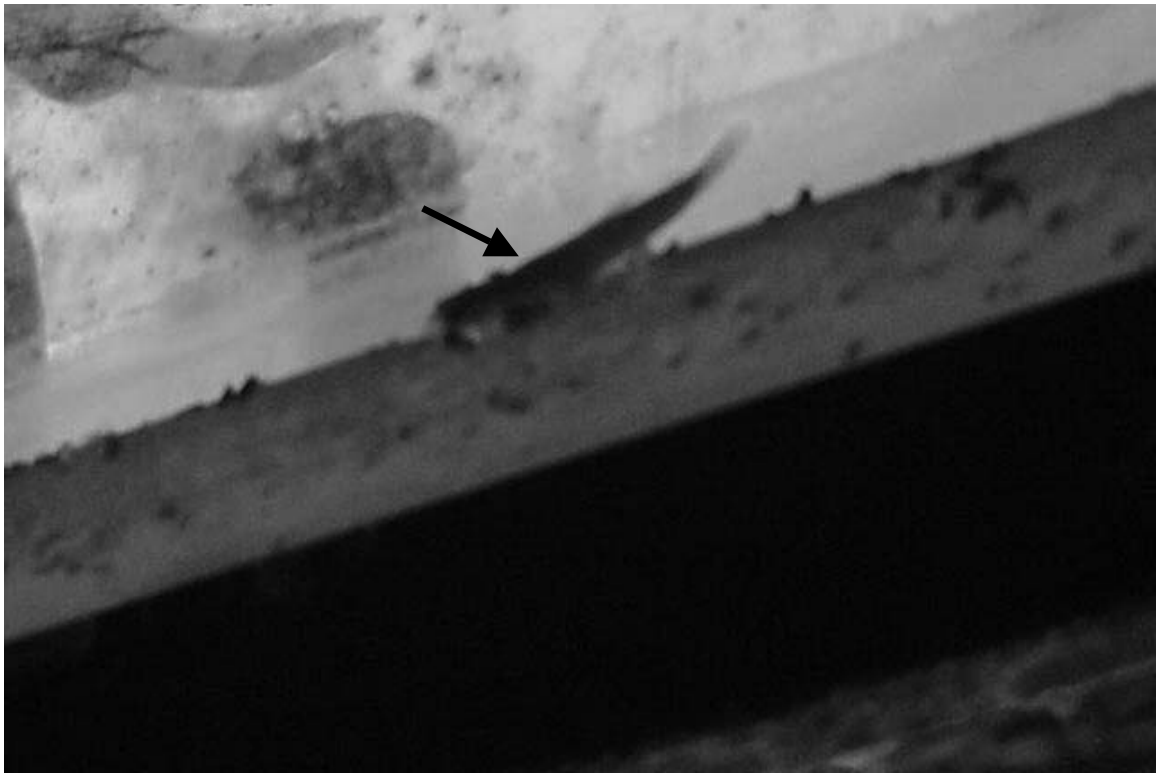
Picture 7

Plants and standing water

Picture 8

Algal growth in aquarium

Picture 9



Decaying fish in aquarium

Picture 10

Clinging plant growth on building exterior

Picture 11

Plant growth close to building. Shrubbery located in front of fresh air intake

Picture 12

Location of vent in relation to ground

Picture 13

Debris in vent

Picture 14

Damaged mortar and missing caulking

Picture 15

Unsealed holes in exterior brickwork

Picture 16

Fungal growth in windowsill

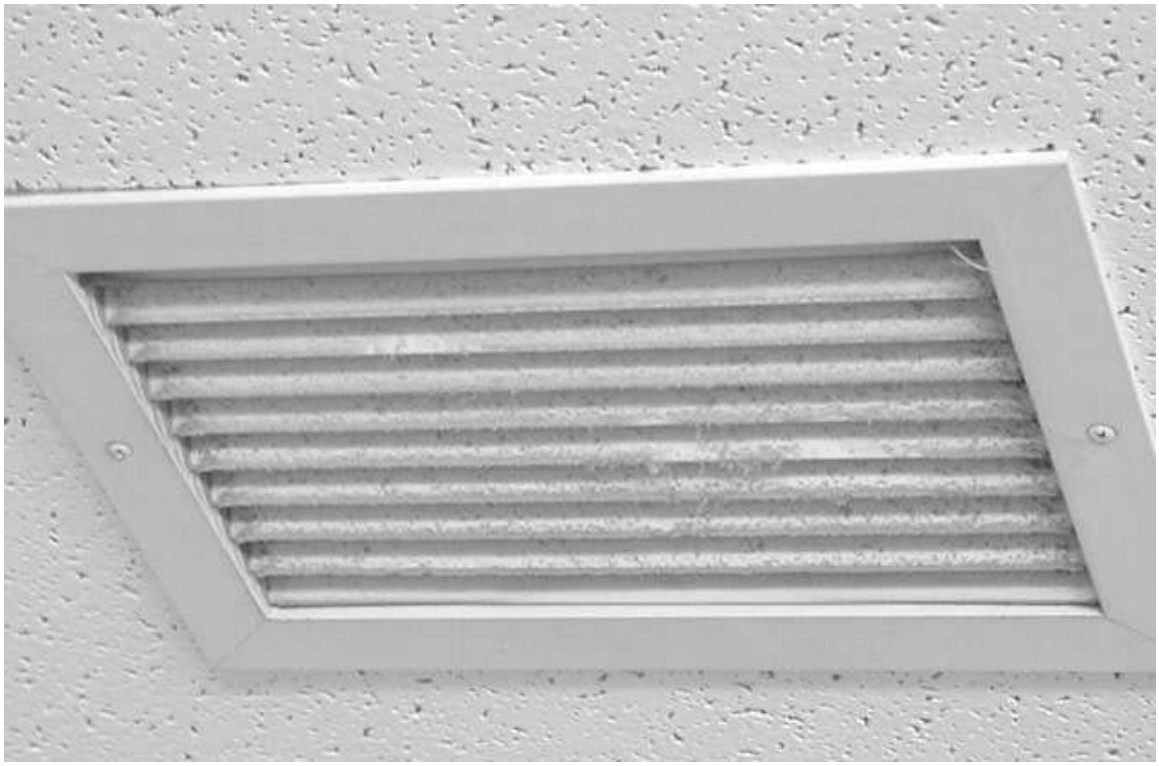
Picture 17

Cabinet drawer with spray cleaning agents

Picture 18

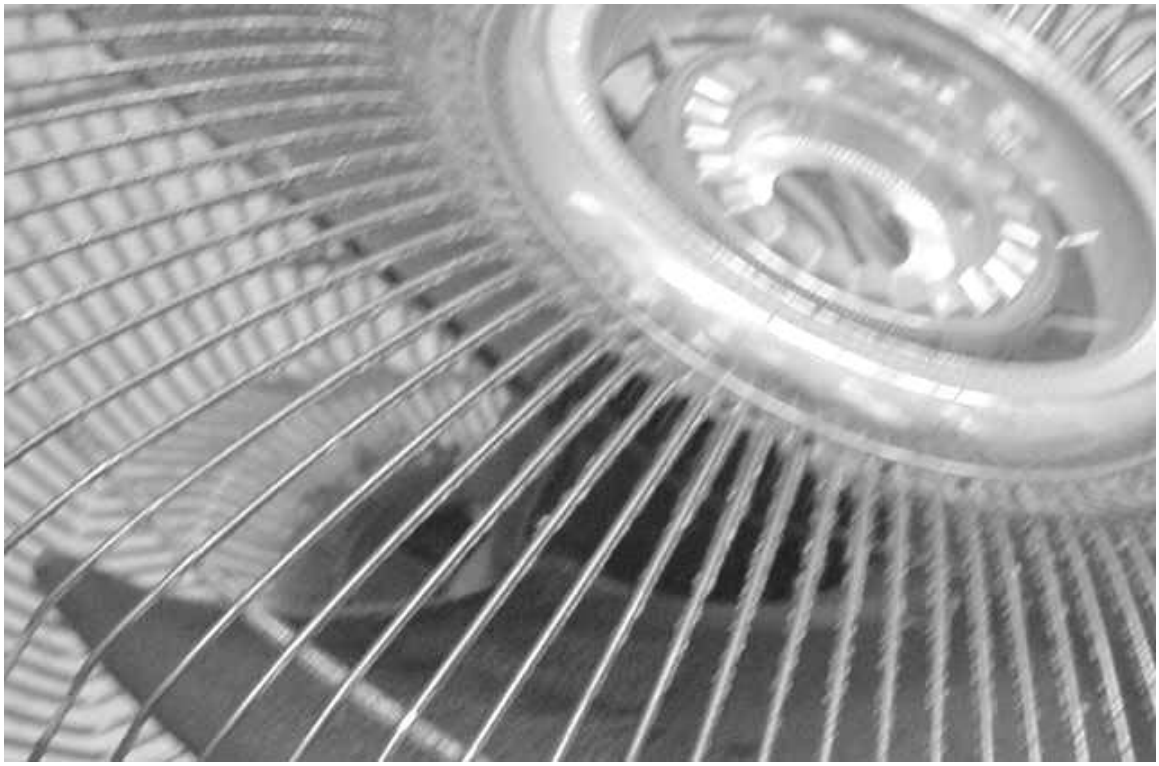
Upholstered furniture

Picture 19



Accumulated dust on exhaust vent

Picture 20



Accumulated dust on personal fan

Picture 21

Items hanging from ceiling

Picture 22

HEPA filtered vacuum held together by duct tape

Picture 23

Sealed and unsealed nests on window sill/univent

Picture 24

Nest on exterior of window frame

TABLE 1

Indoor Air Test Results – Helen R Donaghue School, Merrimac, MA

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	443	78	36					Clear and sunny Wind: East, ~ 5-10 mph
Room 10	900	73	42	19	Y	Y	Y	DO; WO; CD; cleaner and plant food storage; items on univent; upholstered furniture; exhaust obstructed and off
Room 9	1153	76	38	23	Y	Y	Y	WO; univent and exhaust obstructed; exhaust off; items hanging from CT; space in sink countertop; cleaner storage; DEM
Room 11	1536	76	38	22	Y	Y	Y	DO; cleaners stored under sink; univent and exhaust off; univent obstructed; CD; DEM; soil/sand/mud in containers
Room 8	1769	76	40	22	Y	Y	Y	DO; space in sink countertop; cleaner and plant food storage; univent obstructed; exhaust off; location of plants

ppm = parts per million parts of air
DEM = dry erase materials
DO = door open
CD = chalk dust
CT = ceiling tile
WO = window open
WD = water damage

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Room 12	1960	76	39	2	Y	Y	Y	20 occupants left 2 minutes prior to assessment; DO; WO; exhaust off; upholstered furniture; aquarium
Room 13	1480	76	37	22	Y	Y	Y	DO; DEM; exhaust obstructed and off; personal fan dusty; cleaner storage; univent weak and rattling; seam between sink/countertop; unlabeled spray bottle
Room 14	986	76	36	19	Y	Y	Y	DO; DEM; terrariums; aquarium with algal growth; seam between sink/countertop; plants; exhaust obstructed and off
Room 15	840	77	36	19	Y	Y	Y	DO; WO; DEM; CD; cleaner storage; items hanging from ceiling; exhaust obstructed

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						Supply	Exhaust	
Room 16	652	77	34	2	Y	Y	Y	20 students left ~25 minutes prior to assessment; DO; WO; DEM; exhaust obstructed and off, seam between sink/countertop; cleaner storage
Room 7	682	76	37	4	Y	Y	Y	DO; room divided by bookcase; exhaust off; univent on high
Library	530	77	34	22	Y	Y	Y	WO; ceiling exhaust off
Media/computer room	922	78	36	2	Y	Y	Y	27 computers; exhaust off; univent off; window A/C fan off
Teacher's lounge (2nd floor)	933	76	34	4	Y	N	Y	Water cooler on carpet; debris in water cooler catch basin
Teacher's work room (2nd floor)	1300	74	36	7	N	N	Y	DEM
Cafeteria	110	73	39	~100	N	Y	Y	DO
Room 18	1140	73	41	0	Y	Y	Y	Plants; DEM; univent obstructed, weak flow; terrarium; aquarium; items hanging from CT; exhaust off; upholstered chair

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						Supply	Exhaust	
Room 19	623	76	38	0	Y	Y	Y	DO; exhaust partially obstructed; Personal fans; 3 CT-WD; items hanging from CT
Room 20	573	75	36	0	Y	Y	Y	DO; WO; terrarium; aquarium with dead fish and algae; DEM; unlabeled cleaners
Room 17	533	75	36	0	Y	Y	Y	DO; Items hanging from CT; terrarium; exhaust off; univent obstructed
Room 26	615	78	37	19	Y	Y	Y	DO; WO; items hanging from CT; CD; DEM; space in sink countertop
Room 22	819	79	37	19	Y	Y	Y	CD; space in sink countertop
Room 24	598	79	35	0	Y	Y	Y	DO; WO; plant debris in univent; items hanging from CT; exhaust off
Room 23	504	79	33	0	Y	Y	Y	DO; WO; CD; exhaust off; items on univent; items hanging from CT; univent partially obstructed; space in sink countertop

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						Supply	Exhaust	
Room 21	535	76	37	0	Y	Y	Y	DO; aquarium; terrarium; plants in standing water, on univent; space in sink countertop; personal fan; items hanging from univent; 2 CT-WD; univent rattling; personal fan
Room 21 (with occupants)	770	78	35	8	Y	Y	Y	
Gym	744	73	34	0	N	Y	Y	Both ceiling AHUs off
Office copy room	791	78	36	0	N	N	Y	Exhaust off
Main office	770	776	37	0	Y	Y	Y	WO; exhaust off; plant on window sill
Principal's office	630	76	36	0	Y	Y	Y	Exhaust off; plants
Conference room	670	76	36	4	Y	N	Y	WO; DEM; exhaust off
Guidance office (main)	600	76	36	0	Y	N	Y	Exhaust off

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TABLE 1

Indoor Air Test Results – Helen R Donaghue School, Merrimac, MA

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Guidance office (inner room)	600	75	36	0	Y	N	Y	Exhaust off
Acitivty room	820	76	37	26	Y	Y	Y	WO; items hanging from ceiling; exhaust off; mud; upholstered furniture; debris in univent; cleaner storage; space in sink countertop; DEM; soil and sand

ppm = parts per million parts of air
DEM = dry erase materials
DO = door open
CD = chalk dust
CT = ceiling tile
WO = window open
WD = water damage

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%